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Understanding Soft Operations Research: The methods, their application and its future in the Defence setting

Rebecca Heyer

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Rebecca Heyer

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DSTO-GD-0411

ABSTRACT

This paper seeks to understand soft operations research (OR) – the distinctions between it and hard OR, its methods and their application, particularly in the Defence setting. To achieve this a detailed examination of selected soft OR methods is presented, followed by a literature review documenting applications of these methodologies in the Defence setting, and the development of a preliminary framework to guide application of the methods. The paper concludes with an examination of the way forward for soft OR in the Defence setting, recommending support for soft OR's use in future projects, either singularly or in combination with hard OR methods; and the development of a framework for incorporating soft OR into current military operations research.

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Executive Summary

Operations research (OR), according to the Australian Society for Operations Research (ASOR), "is concerned with analysing complex problems and helping decision makers work out the best means of achieving some objective or objectives" (ASOR website). In recent years doubts have been raised over the value of traditional OR. These doubts have not been related to the correctness or validity of the techniques employed, but rather their applicability to certain problems; problems that have become increasingly difficult to model mathematically. Critics (including Ackoff, 1979 and Checkland, 1983) argue that OR practice has been considerably more diverse; that problems have become increasingly complex; and that standard formulations of OR methodology cannot cope with these less well-behaved situations. It was in their ability to address these increasingly complex problems that soft OR methods gained credence. As opposed to the traditional or hard methods, soft OR employs predominantly qualitative, rational, interpretative and structured techniques to interpret, define, and explore various perspectives of the problems under scrutiny. Soft OR includes methods such as Checkland's Soft Systems Methodology, Cognitive Mapping, Scenarios Planning, Strengths Weaknesses Opportunities and Threats and Political Economic Sociocultural and Technological analyses, and Strategic Options Development and Analysis. Such methods generate debate, learning, and understanding, and use this understanding to progress through complex problems.

"In a changing world, the Department of Defense has to cope with increased uncertainty about requirements, rapid changes in technology, changes in organizational structures, and a widening spectrum of missions and operations" (Levis & Wagenhals, 2000, p. 225). It is surprising then that soft OR has been scantily applied in the Defence setting in recent years as the methods have a lot to offer in addressing some of these issues. Although surprising, the lack of soft OR studies within the Defence setting is perhaps not unexpected as the choice of methods to use in any particular OR study is as much a product of the knowledge, experience and skills of the researcher as it is about the nature of the problem itself. With the majority of researchers in the Defence setting originating from the hard schools of thinking, such as mathematics, computer science and engineering, it is only natural that they would prefer to apply corresponding methods (Mingers, 2001). Examples of soft OR applications in the Defence setting include its use in a wide range of futures studies (reported by Davies et al., 2001); to determine a strategy for managing the evacuation of civilians from a country undergoing civil disorder (Holt, 1999a); to understand and model information dominance in battle management (Perusich & McNeese, 1998); to

analyse the acquisition and management of logistics in the Australian Defence Force (Sparks, 1997); and for the development of military information operations capability in the Australian Defence Force (Staker, 1999).

The future for soft OR in the Defence setting, in the short term at least, seems to be in its ability to complement hard methods, particularly in response to complex problems. Although there are relatively few combinations of hard and soft OR methodologies being used today, combining methods has been judged to be very successful. In the Defence setting, "successful complementary use of hard and soft methods can have a number of significant advantages including minimising judgement, promoting awareness and improving buy-in for studies" (Clutterbuck, 2001). Clearly soft OR has much to offer Defence researchers. In order for it to become a key force in military operations research, however, it needs to be viewed as equally useful in the operations researcher's toolkit; a framework for incorporating it into current research should be developed; and there needs to be development of skills in the area.

Contents

1. OPERATIONS RESEARCH - AN OVERVIEW	1
1.1 Introduction.....	1
1.2 Hard Operations Research.....	2
1.3 Soft Operations Research	3
2. SOFT OPERATIONS RESEARCH - AN OVERVIEW.....	5
2.1 Checkland's Soft Systems Methodology	5
2.2 Viable Systems Model	6
2.3 Total Systems Intervention	7
2.4 Decision Trees and Influence Diagrams	8
2.5 Cognitive Mapping.....	9
2.5.1 Journey Making.....	9
2.5.2 Strategic Options Development and Analysis.....	10
2.6 Strategic Choice Approach	11
2.7 Strategic Assumption Surfacing and Testing.....	12
2.8 Scenario Planning	12
2.9 Interactive Planning.....	14
2.10 Robustness Analysis.....	15
2.11 Meta- and Hypergames	15
2.12 Repertory Grid Technique	15
2.13 Delphi Methods.....	16
2.13.1 Sequence of Opportunities and Negatives.....	17
2.13.2 Policy Delphi	17
2.13.3 Decision Delphi.....	17
2.13.4 On-site Conferencing and Researching	17
2.13.5 Qualitative Controlled Feedback.....	17
2.13.6 Ethnographic Delphi Futures.....	17
2.13.7 Imen Delphi.....	18
2.14 Political Economic Sociocultural and Technological, and Strengths Weaknesses Opportunities and Threats Analyses	18
2.15 Multimethodology.....	19
3. SOFT OPERATIONS RESEARCH IN THE DEFENCE SETTING	19
3.1 A Literature Review.....	20
3.2 Accounting for the lack of Soft Operations Research studies in the Defence setting	21
4. FUTURE DIRECTIONS FOR SOFT OPERATIONS RESEARCH IN DEFENCE. 22	22
4.1 Multimethods and Multiparadigms - Introducing Composite Operations Research	23
4.2 The Contributions of Soft Operations Research - the Case of Asymmetric Conflict.....	24
4.3 The Future of Soft OR in the Defence Setting	26
4.4 A Preliminary Framework to Guide the Application of Soft Operations Research Methodologies.....	26
5. CONCLUSION.....	28
6. REFERENCES	29

APPENDIX A: AN APPLICATION OF CHECKLAND'S SOFT SYSTEMS
METHODOLOGY.....35

Glossary

ADF	Australian Defence Force
ASOR	Australian Society for Operations Research
BR	Behaviour Representation
CATWOE	Customer, Actors, Transformation, Worldview, Owner, Environment (pneumonic)
CIA	Central Intelligence Agency (USA)
DD	Decision Delphi
DERA	Defence Evaluation and Research Agency (UK)
DSTO	Defence Science and Technology Organisation (AUS)
EDFR	Ethnographic Delphi Futures Research
HBR	Human Behaviour Representation
ID	Imen Delphi
JM	Journey Making
MNLOE	Multinational Limited Objective Experiment
MOD	Ministry of Defence (UK)
MORS	Military Operations Research Society
NASA	National Aeronautics and Space Administration (USA)
NATO	North Atlantic Treaty Organisation
OR	Operations Research
OSCAR	On-site Conferencing and Research
PD	Policy Delphi
PEST	Political, Environmental, Social and Technological (analysis)
PJHQ	Permanent Joint Headquarters (UK)
QCF	Qualitative Controlled Feedback
RA	Robustness Analysis
RGT	Repertory Grid Technique
SAST	Strategic Assumption Surfacing and Testing
SCA	Strategic Choice Approach
SODA	Strategic Options Development and Analysis
SOON	Sequence of Opportunities and Negatives
SSM	Soft Systems Methodology
STEP	Social, Technological, Environmental, Political (analysis)
SWOT	Strengths, Weaknesses, Opportunities and Threats (analysis)
TCA	Theatre Command Analysis (Branch)
TSI	Total Systems Intervention
USAF	United States Air Force
VSM	Viable Systems Model

1. Operations Research – An Overview

1.1 Introduction

Operations research (OR), according to the Australian Society for Operations Research (ASOR), “is concerned with analysing complex problems and helping decision makers work out the best means of achieving some objective or objectives” (ASOR website). OR rose to prominence during World War II largely due to the British military. In the days leading up to World War II, British military management assembled a group of scientists to apply a scientific approach to military operations to determine the most advantageous ways to deploy their massive materiel and manpower. Soon after, the United States military began engaging in OR using specialists from fields such as chemistry, mathematics, and engineering to create management techniques for allocating scarce resources and to achieve both military and industrial goals (Carter & Price, 2001). In the 1950s various academic societies were born in both Britain (who today prefer the term operational research) and the United States (who prefer the term management science) for operations researchers (those who practice OR) to promote, develop and exchange ideas in the field. These professional societies remain active today and the field of OR has grown even larger and more diverse.

OR uses tools from a wide variety of disciplines including statistics, mathematics, and engineering (see Table 1 for some examples), and is now applied not only to military problems, but those in the industrial, transportation, business, health and crime realms.

Table 1: A selection of OR methodologies adapted from Carter & Price (2001)

Linear Programming	A mathematical technique of assigning a fixed amount of resources to satisfy a number of demands in such a way that some objectivity is optimised and other defined conditions are also satisfied.
Queuing Theory	A theory to help calculate the expected number of people in a queue, expected waiting time, expected idle time etc. This theory is applied to situations where measures have to be taken to minimise the extent and duration of a queue with minimum investment cost.
Game Theory	A theory used for decision-making under conflicting situations where there are one or more opponents, with different objectives, that each influence the outcomes of the game. Game theory provides solutions to the games based on the assumption that all players want to maximise their profits and minimise losses.
Simulation	A technique that involves setting up a model of a real situation and then performing experiments to learn more about a situation.
Markov Process	A technique used in situations where various states are defined and the system moves from one state to another on a probability basis. The technique allows researchers to calculate the probability of being in a particular state.

In very crude terms OR can be seen as a series of steps (Carter & Price, 2001):

1. **Formulation of the Problem** – the operations researcher gathers sufficient information (through research and site visits) to understand the organisational

- climate, objectives, expectations and alternative causes of action. Only then can a problem be adequately formulated.
2. **Develop the Model** - the operations researcher then expresses the problem as a model that represents the systems, processes and/or environment in terms of equations, relationships or formula.
 3. **Select and Collect Data Input** - the operations researcher must then ensure they have sufficient data input to operate and test the model.
 4. **Solution to the Model** - the operations researcher then finds a solution to the problem which invariably involves considerable updating and modification.
 5. **Validation of the Model** - the operations researcher must ensure that the model is valid: that it can provide a reliable prediction of the system's performance and be applicable over time, or updated to reflect past, present and future aspects of the problem.
 6. **Implementation** - while implementation remains the domain of the implementing authority, the operations researcher should work closely with management to play a positive role in implementing the solution.

The advantages of OR are better control, better systems, better decisions, and better coordination in an organisation. The limitations of OR include the many non-quantifiable factors present in complex problems which are difficult to model using traditional OR techniques; the distance between the operations researcher and management; and implementation - operations researchers rarely have the understanding of the complexities of human relations and behaviour required to effect implementation (Carter & Price, 2001).

1.2 Hard Operations Research

The OR described above has in recent times been referred to as hard or traditional OR. The word 'hard' refers to the use of mathematical and quantitative techniques as opposed to softer research that employs predominantly qualitative techniques (soft OR will be discussed in detail in section 1.3). For instance, techniques that involve subjective probabilities, such as Bayesian Belief Networks, the Analytical Hierarchy Process and Multiple Criteria Decision Making, are deemed hard OR because of their quantitative focus. Other writers have defined the hard distinction in terms of its primary and secondary foci. For hard OR the primary focus is on the problem, the people involved with the problem are the secondary focus (Pidd, 1999).

In recent years the limitations of OR have become particularly evident. These limitations are not related to the correctness or validity of the techniques employed, but rather to the applicability of quantitative techniques to certain problems (Beasley, 2002). Traditional or hard OR has taken as its "foundation the possibility of a single uncontested representation of the problem situation under consideration" (Rosenhead, 1996, p.118). Critics (including Ackoff, 1979 and Checkland, 1983) have argued that OR practice has been considerably more diverse than this; that problems have become increasingly complex; and that standard formulations of OR methodology cannot cope

with these less well-behaved situations. In Checkland's words "the weakness of OR...is that it is wedded to logic in situations in which logic is not necessarily paramount" (Checkland, 1983, p. 668). OR, they argue, requires methods that enable decision makers to accommodate multiple perspectives; facilitate negotiating joint agendas; function through interaction and iteration; and generate ownership of problem formulation. This is where soft OR has stepped in.

1.3 Soft Operations Research

"Soft OR is not soft in the sense of being soft-headed, irrational or lacking in rigour" (Pidd, 1999, p.1). The soft in soft OR simply refers to the orientation of the approach as qualitative or interpretative rather than quantitative, as is the focus of hard OR. The distinction between hard and soft OR is perhaps best highlighted by the underlying assumptions of each school of thinking. These are presented below in Table 2.

Table 2: The Assumptions Made by Hard and Soft OR (Munro & Mingers, 2002)

HARD OR	SOFT OR
<ul style="list-style-type: none"> ▪ There is a single decision maker (or consensual group) with a clear objective. ▪ The nature of the problem is agreed. ▪ The most important factors in a problem can be quantified and reliable data collected. ▪ A model, often mathematical or computer-based, can be used to generate solutions. ▪ Future uncertainties can be modeled using probability theory. ▪ There is no need for the methods used to be transparent to clients. ▪ The role of the hard OR specialist is one of expert analyst. ▪ Hard operations researchers, generally speaking, require good analytical skills and a sound knowledge of mathematics and computing. 	<ul style="list-style-type: none"> ▪ There are a range of decision makers or groups with differing or conflicting objectives. ▪ The nature of the problem is not well defined. ▪ Many important factors in a problem cannot be quantified. ▪ Mathematical models, therefore, cannot be used. ▪ Uncertainties cannot be reduced to probabilities. ▪ The methods used must be transparent and accessible to clients. ▪ The role of the soft OR specialist is one of facilitator with a group of participants. ▪ Soft operations researchers, generally speaking, require sound people skills and the ability to facilitate often stressful and contentious workshops.

In the 1970s, 80s and 90s, it had become obvious that some organisational problems could not be solved by pure logic, employing hard OR. Indeed problems have continued to become more complex and increasingly difficult to model mathematically.

Underlying these difficulties is the fact that organisations are made up of people and people simply do not act like machines. Soft OR has sought to readdress this by understanding that people are an integral part of organisations and that these people each bring to the organisation their own worldviews, interests and motivations. Furthermore, soft OR understands the difficulties involved in the predictability of human behaviour. Soft OR techniques invariably employ a researcher whose role it is to ensure the study group contains key stakeholders; to act as a facilitator of the process; to orchestrate discussions; and be seen as open, independent and fair. The idea is to capture the group's perception of the problem both verbally (as words are the natural currency of a problem) and in diagrams (which help to structure the group's perception and depersonalise the debate). Soft OR methods seek to help key stakeholders understand the problems they face; the views held by other stakeholders; negotiate the action to take; and agree to a consensus on a course, or courses, of action to be taken (Daellenbach, 2002). In very general terms, therefore, soft OR methods are those that structure a problem, as opposed to hard OR that seeks to solve it. Soft OR uses predominantly qualitative, rational, interpretative and structured techniques to interpret, define, and explore various perspectives of an organisation and the problems under scrutiny. They generate debate, learning, and understanding, and use this understanding to progress through complex problems. It is for this reason that the great majority of such soft OR methods are referred to as "problem structuring methods" (Rosenhead, 1980).

It is pertinent to mention here that there has been considerable debate as to whether soft OR is a legitimate branch of OR (Checkland, 1983; Checkland, 1999, Holt & Pickburn, 2001). An article featuring cognitive mapping, a widely used soft OR method, published in the *Journal of the Operational Research Society* in 1980 received a barrage of criticism describing the method and those like it as having "no content" and heralding that "this kind of article is not operational research" (Machol, 1980, p. 1109). Criticisms such as these continue today; including questions about repeatability and robustness; inclusion of perceptions and other subjectivities that are ill-founded; and questions about the expertise of soft operations researchers (Holt & Pickburn, 2001). For instance Beasley (2002) labelled soft OR a religion complete with followers whose belief is based on faith rather than evidence! Others have questioned whether the results achieved through application of soft OR methods could have just as easily been achieved using other methods (Omerod, 2001). In response to such criticisms, soft operations researchers concede that one would expect such mixed feelings about the use of soft OR methods, particularly those used in place of traditional or harder ones (Holt & Pickburn, 2001). They add: "many soft methods aim to be subjective as they are designed to elicit the perceptions of the various parties for study purposes...soft methods are generally used for problem structuring, in the early stages of a study, where insight rather than rigour is the goal...when that insight has been gained there is usually no requirement for repeatability at high level" (Holt & Pickburn, 2001, p. 3). To further understand, and perhaps legitimise, the use of soft OR, there is a general consensus among operations researchers that with increased use "the auditability within soft methods should be exploited" (Holt & Pickburn, 2001, p. 9).

2. Soft Operations Research - An Overview

A discussion of selected soft OR methodologies appears below. This is not an exhaustive list by any means, but covers the methodologies most commonly used by soft operations researchers today (Munro & Mingers, 2002). While there is a general consensus as to what methodologies fall under the soft OR heading, it appears that most methodologies have simply been borrowed or adapted from those used in other disciplines including the systems sciences and the social sciences (predominantly sociology, psychology and political science).

2.1 Checkland's Soft Systems Methodology

Perhaps the most well known and widely used of the soft OR methodologies is Checkland's Soft Systems Methodology (SSM), see Checkland (1999) for a comprehensive historical review. There are several stages in the SSM process, not necessarily followed in a linear fashion.

- **Stages 1 & 2 Confronting the Problem Situation** - these stages involve entering the problem situation and identifying within it the people, culture and norms through interviews and discussions, observations, brainstorming and rich pictures. Rich pictures are highly contextual cartoon-like representations of the actors, issues, problems, processes, relationships and conflicts of a situation, that provide an idea of the climate of the situation. Rich pictures capture the essence of a situation and help to identify relevant themes and ensure a shared understanding of different perspectives.
- **Stage 3 Developing Root Definitions** - in this stage root definitions need to be stated, this is a requirement of SSM. A root definition is a sentence that describes the ideal system: its purpose, who will be in it, who is taking part in it, who could be affected by it and who could affect it. To construct a root definition a technique known as CATWOE is employed. CATWOE is a mnemonic acronym used by problem owners to formulate a root definition by considering the following of the desired system:
 - C - Customer: who are the customers, beneficiaries, victims of the system?
 - A - Actors: who are the actors, participants in the system?
 - T - Transformation Process: what is transformed by this system?, what inputs are transformed into what outputs?
 - W - Weltanschauung (Worldview): what is the worldview underlying the system?
 - O - Owner: who is the owner of the system?, who has the power to stop the system?
 - E - Environmental Factors: what are the environmental constraints that need to be considered?

A series of root definitions are usually constructed from this process. Group discussions are then used to try and reach agreement on one applicable root definition or to decide on a few for further consideration.

- **Stage 4 Building a Conceptual Model** – in SSM a model is a diagram of activities with links connecting them. The model is developed directly from the root definition using action statements describing the activities which are needed by the root definition. The model should contain between 5 and 9 activities which are linked according to logical dependencies (activity x is dependent on activity y, for instance). The idea is to better demonstrate and understand activities needed in the transformation process; debate the different perspectives held about the activities and their linkages; and develop a shared understanding of these different perspectives.
- **Stage 5 Comparing Models with the Real World** – this stage is designed to bring structure and substance to an organised debate about improving the current situation. The models are compared with the real world by ordered questions for every activity and link in the model. Group members are asked: does this happen in the real situation?, how?, by what criteria is it judged?, is it a concern in the current situation?
- **Stage 6 Identifying Changes** – this stage involves identifying systematically desirable and culturally feasible changes to the real world system, that appear to those involved in the SSM process as worth trying.
- **Stage 7 Taking Action** – this stage involves putting the changes identified in Stage 6 into practice, usually through the development and enactment of an action plan.

In order to provide a more thorough explanation of SSM in practice, Appendix A provides a practical example of the application of the methodology. In summary then SSM works by defining systems of purposeful activity (the root definition), building models of a number of relevant systems, and comparing these models to the real world, in order to structure a debate focusing on the differences. The idea is that this debate should lead the group involved in the process to identify changes to be made, how they will be made, and motivate each other to make the changes (Travis & Venable, 2002).

2.2 Viable Systems Model

The Viable Systems Model (VSM) presents a theory of organisational viability by applying notions from cybernetic theory to organisations (Beer, 1985). The underlying assumption of the model is that the central task for any organisation is to strive for viability, which Beer defines as being able to maintain a separate existence. In order to achieve this separate existence and therefore viability, Beer asserts that the following five functions must be properly implemented:

Function 1 – Collection of Primary Activities: the primary activities realise the identity of a viable system. In a research organisation, for instance, the primary activities would include doing research and providing advice.

Function 2 - Coordination: the coordination function ensures that the interdependencies between the primary activities are coordinated.

Function 3 - Control: the control function ensures synergy among the primary activities and monitors whether the goals of these activities are being realised.

Function 4 - Intelligence: the intelligence function initiates adaptation of new organisational goals by ensuring that the activities of the organisation remain aligned with environmental developments.

Function 5 - Policy: the policy function links control and intelligence and ensures that the organisation defines its identity and long-term strategy.

Applications of the VSM seek to critically examine each of these functions in consultation with key stakeholders in an organisation. Both the goals (desired outcomes for the specific variables) and the signals (actual outcomes for the specific variables) are assessed to identify gaps. Gaps can then be closed through adjustment of the goal or through implementing certain interventions to realise the goal. With all gaps closed the five functions can be successfully implemented and viability obtained (Achterbergh & Vriens, 2002).

2.3 Total Systems Intervention

Total Systems Intervention (TSI) is a methodology designed to enable the choice of an appropriate systems methodology for any particular problem situation (Flood & Jackson, 1991). TSI comprises three stages:

1. **Creativity Phase** - this is essentially the information-gathering phase with the aim of gathering a wide range of stakeholder understandings and perceptions of the problem situation. The creativity phase includes observation, document analysis and face-to-face inquiry.
2. **Choice Phase** - the information gathered in the creativity phase is then classified according to whether the system is simple (mechanical) or complex (systemic); and whether the nature of the relationship between the participants is unitary (general agreement), pluralist (differing views, but agreement could be reached), or coercive (high degree of conflict, difficult to reach agreement) (Daellenbach, 2002). This classification is in line with the Systems of Systems Methodology (SOSM) described in greater detail by Flood & Jackson (1991). The problem situations are then mapped to methodologies according to the following table.

Table 3: A System of Systems Methodologies (Warren & Adman (1999) p. 355).

	Unitary	Pluralist	Coercive
Simple	Hard OR, Systems Analysis, Systems Engineering	Social Systems design, Strategic Assumption Surfacing and Testing	Emancipatory Systems Thinking, Critical Systems Thinking
Complex	Cybernetics, General Systems Theory, Socio-technical, Contingency Theory	Soft Systems Methodology, Interactive Planning	Emancipatory Systems Thinking

3. **Implementation Phase** – once the appropriate methodology is chosen it is applied to effect the desired change. Given the scope of methodologies that may be chosen it is not relevant to detail here the different forms that the implementation phase may take.

2.4 Decision Trees and Influence Diagrams

A decision tree is a tool for helping a decision maker to choose between several courses of action. Decision trees (see Figure 1a) provide a highly effective structure within which decision makers can lay out options and investigate the possible outcomes of choosing those options. They also help to form a balanced picture of the risks and rewards associated with each possible course of action (see Carter & Price, 2001 for more on decision trees).

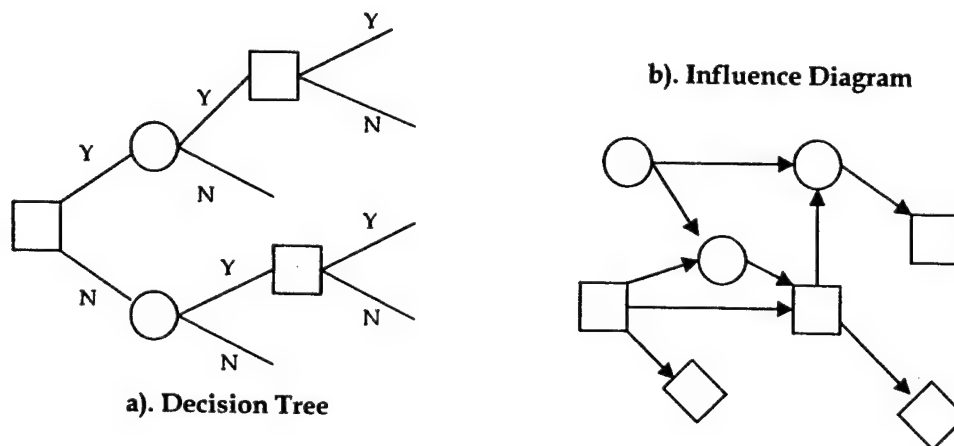


Figure 1: Decision Tree and Influence Diagram – A Comparison

An influence diagram (see Figure 1b) is a simple visual representation of a decision problem. It provides an intuitive way to identify and display the essential elements, including decisions, uncertainties, and objectives and how they influence each other (Howard & Matheson, 1981). The influence diagram was developed to substitute conventional decision trees in modelling and for solving real world decision problems (see Howard & Matheson (1981) for more on influence diagrams). Both decision trees and influence diagrams are worthwhile tools and they complement each other well. Influence diagrams are particularly valuable for the structuring phase of problem solving and for representing large problems. Decision trees, on the other hand, display the details of a problem. Influence diagrams and decision trees are isomorphic; that is a problem represented in an influence diagram can generally be converted into a decision tree, and vice versa. One strategy commonly adopted is to start by using an influence diagram to help understand the major elements of the situation and then convert to a decision tree to fill in the details. Specific probability and value inputs

may be added to both the influence diagram and decision tree to quantify decisions being made, to evaluate the decisions. This is the common application of both decision trees and influence diagrams in OR, and comes under the guise of hard OR as they then become problem solving (rather than purely problem structuring) methods.

2.5 Cognitive Mapping

Cognitive mapping, a form of influence diagram, is a technique that has been used by a variety of researchers in a variety of settings. Cognitive maps provide a holistic picture of an individual's overall perspective, without the loss of any detail; enabling researchers to move beyond the assumption of internal consistency to the detailed assessment of specific concepts within the map. For OR, this means gaining a better understanding of the client's perception of a problem which is vital for a successful OR study. In cognitive mapping, self-defined constructs represent the 'causal knowledge' of a decision maker in the form of a map of their own subjective world. Cognitive maps can be seen as a model of action-orientated thinking about a situation where arrows signify influences in a line of argument linking cause and effect (Eden, 1992). Cognitive maps can be analysed through interpretative coding (where individual concepts are interpreted); in terms of their content (the meanings they contain); and in terms of the complexity of configuration of the maps (for example, link to node ratio, cluster analyses). Two applications of cognitive mapping regularly used in OR studies are presented below.

2.5.1 Journey Making

Journey Making (JM), (where Journey stands for JOintly Understanding, Reflecting and NEgotiating Strategy), is used to facilitate and structure understanding and accommodation in the course of developing organisational strategic options (Eden & Ackermann, 1998). JM has an underlying assumption that all organisations have some degree of strategic direction, whether coordinated or uncoordinated; conscious or unconscious. JM is a methodology for thinking about what strategising currently occurs in the organisation; what options there are for different strategic directions; and how those directions could be realised. JM is designed to deal with the particular complexities that arise when gaining an understanding of these three things. It deals particularly well with the complexities of the organisational environment (the external complexity) and the complexities of formulating strategies given a wide variety of views and interests (the internal complexity). In this way it is a useful methodology for use in situations where there is no clear consensus as to the way forward.

In very simple terms JM consists of two stages:

1. **Surfacing Emergent Strategies** - this stage is devoted to understanding the situation, the cultural issues, the people involved and their roles. Individual cognitive maps are developed to better understand the issues, these are then combined to produce strategy maps and then analysed to identify emergent strategies.

2. **Reflecting and Negotiating to Gain Agreement** - in this stage the most important problems are selected and a series of options and scenarios are developed to deal with them. Each option and scenario is then evaluated and a list of no more than 10 problems and their associated options and scenarios are selected for further discussion. The stage is concluded with the presentation of a report to management outlining the recommendations for further discussion and the set/s of options and scenarios which have the most realistic chance of being implemented successfully.

2.5.2 Strategic Options Development and Analysis

Strategic Options Development and Analysis (SODA) elicits information from members of a group using individual interviews. The information gathered is represented on cognitive maps in order to show that the concepts (or short phrases capturing some idea) are relevant and to show the linkages between the concepts (Eden, Jones & Sims, 1983). Concepts within cognitive maps are generally either goals (appearing at the head/top of the map, self-evidently regarded as good things) or options (appearing at the tail/bottom of the map). Strategic options are those that have no other options above them in the maps (see Figure 2 for an example).

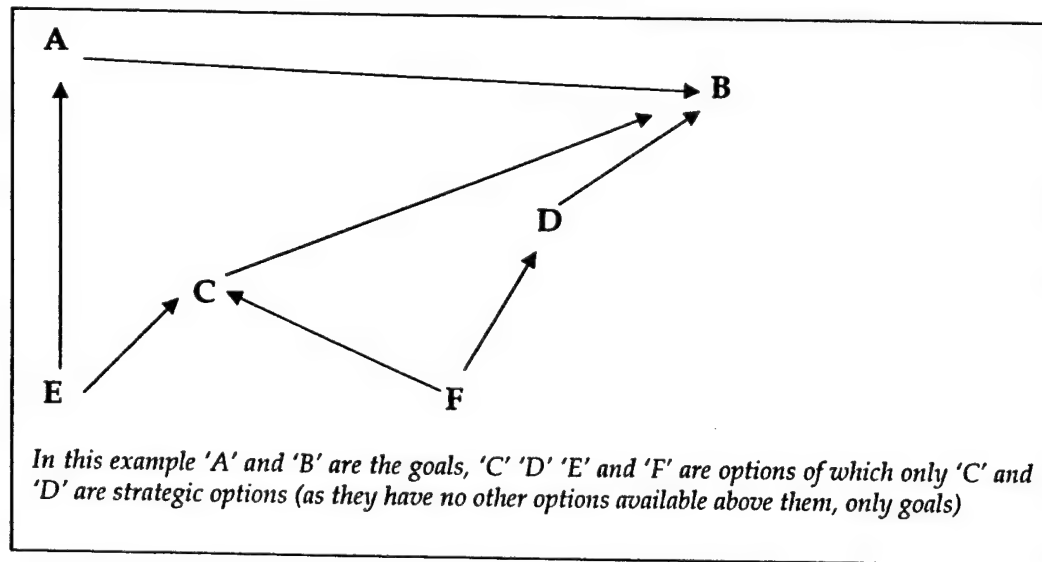


Figure 2: Example of SODA Cognitive Map illustrating goals, options and strategic options

In SODA, individuals are interviewed in a relatively unstructured way to try and elicit their thoughts about the problem under discussion. From this discussion cognitive maps are drawn, like that presented in Figure 2, to help each individual refine their thinking. Once individual maps have been produced for an entire group, they are merged into a single map that can initially contain several hundred concepts. Similar concepts are then merged into one while keeping concepts from key members of the group and maintaining a balance of concepts from all members of the group. To make

the map manageable the concepts are arranged into clusters containing between 15 and 30 concepts. The final merged map is an overview map at the cluster level showing links between each cluster. This map serves as a focus for discussion at a concluding workshop that involves:

- Analysis of the overview map's content and structure;
- Identification of emerging themes and core concepts; and
- Discussion of key goals, inter-related problems, key options and assumptions.

The key aim of SODA is to achieve understanding and agreement among the group members regarding the problem under discussion.

2.6 Strategic Choice Approach

Strategic Choice Approach (SCA) is an interactive planning approach centered on managing uncertainty in strategic situations through a process of communication and collaboration between people with different backgrounds and skills (Friend & Hickling, 1987). SCA focuses on decisions to be made in a particular planning situation, whatever their timescale and whatever their substance, and highlights the subtle judgements involved in agreeing how to handle the uncertainties which surround the decision to be addressed. SCA is an incremental method, rather than one that looks towards an end product of a comprehensive strategy at some future point in time. Through a framework known as the 'commitment package' an explicit balance is agreed between decisions to be made now and those to be left open until some specified time in the future.

There are three key elements of analysis which are used in structuring problems and working towards decisions in SCA:

1. **The Decision Area** - an area where an alternative course of action is possible
2. **The Comparison Area** - where each of the feasible decision schemes are compared and ranked
3. **The Uncertainty Areas** - three types of uncertainty are addressed in the context of proposed decisions:
 - a. Uncertainties to do with the working environment
 - b. Uncertainties to do with guiding values
 - c. Uncertainties to do with related choices or decision fields

In SCA, the facilitator uses four modes of decision-making activity alternated as the facilitator deems appropriate:

1. **Shaping** - considering the structure of decision problems
2. **Designing** - considering possible courses of action
3. **Comparing** - comparing possible courses of action
4. **Choosing** - choosing courses of action

A comparison between the different decision schemes aids in bringing to light the key uncertainties. The group can then identify priority areas for further examination and design explorations and contingency plans (Friend & Hickling, 1987).

2.7 Strategic Assumption Surfacing and Testing

Strategic Assumption Surfacing and Testing (SAST) is used primarily in situations where differences of opinion are preventing a group's ability to tackle an ill-structured problem (Mason & Mitroff, 1981). The method seeks to examine a group's preferred strategy for dealing with a problem by identifying, discussing, and understanding the assumptions on which the strategy is based. The five phases of SAST are:

1. **Group Formation** - the large study group is divided into groups of 6-8 participants (either randomly allocated or purposely assigned) and the focus then turns to team building within the groups.
2. **Assumption Surfacing** - groups are asked to identify the stakeholders that will be affected by the problem at hand; and then asked to generate a list of assumptions relating to those stakeholders that will enable an optimal outcome of the problem.
3. **Intra-Group Rating** - groups are then asked to eliminate irrelevant assumptions and rate the remainder. This is commonly aided by generating an 'Importance/Certainty' matrix (see Mason & Mitroff, 1981) that helps the group to rank their assumptions in priority order.
4. **Inter-Group Debate** - once groups have ranked their assumptions they rejoin the larger group to present their assumptions and engage in a group debate. A combined assumptions list is produced.
5. **Final Synthesis** - once all participants agree that the list of assumptions is thorough, the group sets about prioritising a list of issues, assesses their organisation's state of knowledge with respect to these issues, and develops a list of activities designed to improve knowledge on the issues.

The information obtained from the final synthesis is then used to develop and implement the proposed strategy.

2.8 Scenario Planning

Scenario planning is a method for learning about the future by understanding the nature and impact of the most uncertain and important driving forces affecting our future. It is a group process that encourages knowledge exchange and development of mutual deeper understanding of central issues important to the future. The goal is to craft a number of diverging stories by extrapolating uncertain and heavily influencing driving forces. The stories, together with the work done developing them, have the dual purpose of increasing the knowledge of the environment and widening the perception of possible future events (Schwartz, 1996). The following five steps are offered as a guide.

1. **Identify the Focal Issue or Decision.** There are an infinite number of stories that could be told about the future, the purpose is to tell those that matter, that lead to better decisions. The first step is devoted to agreeing on the issue or question that needs to be addressed.

2. Identify the Primary "Driving Forces" at work in the present. These fall roughly into four categories:

- Social dynamics - demographic and softer issues of values, lifestyle, demand, or political energy.
- Economic issues - macroeconomic trends and forces shaping the economy as a whole.
- Political issues - electoral, legislative and regulatory.
- Technological issues - direct, enabling and indirect.

3. Identify the Predetermined Elements of the Driving Forces - predetermined elements are those that are completely outside of one's control and will play out in any story told about the future.

4. Identify the Critical Uncertainties - uncertainties are those elements left once the predetermined elements have been identified. Critical uncertainties are those that are central to the issue or question being explored. At first, all critical uncertainties seem unique. But clusters of critical uncertainties that have some commonality to a single spectrum can be identified forming an axis of uncertainty. The goal is to simplify the entire list of related critical uncertainties into two orthogonal axes in order to define a matrix (two axes crossing) that allows for the definition of four very different, but plausible, quadrants of uncertainty. Each of these far corners is, in essence, a logical future that can be explored (see Figure 3 below for an example).

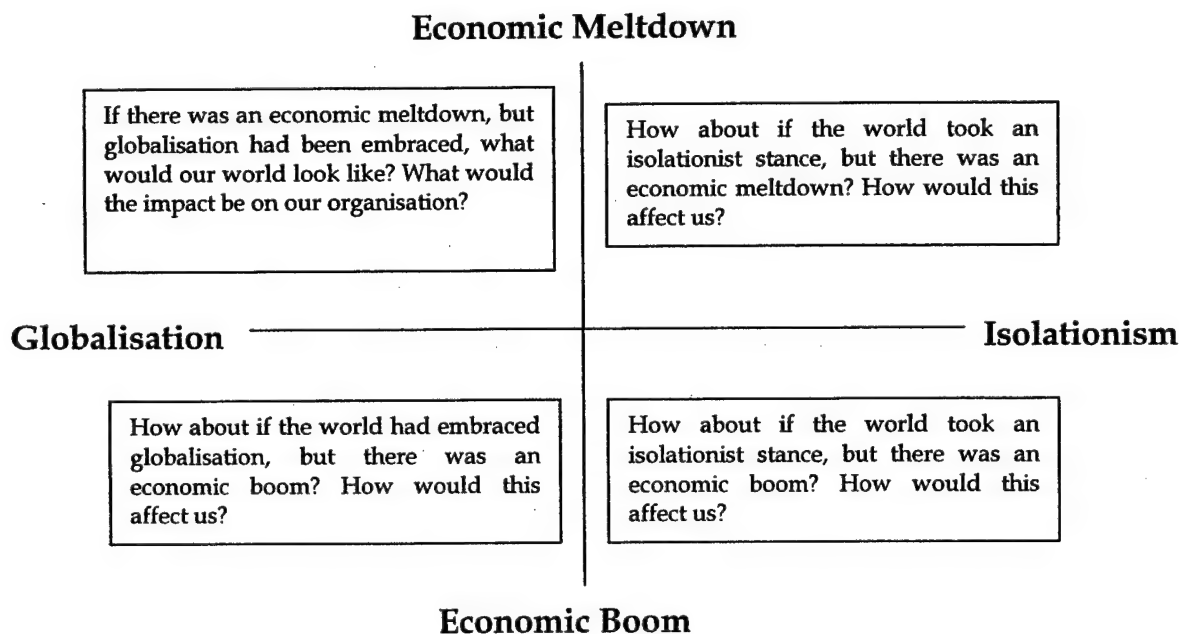


Figure 3: Example of a Scenarios Planning Matrix (where axes of uncertainty are Globalisation/Isolationism and Economic Boom/Meltdown)

Research has shown that there are six driving forces (or key drivers) most commonly cited in futures studies. These are demography; environment; economics; science and technology; national and international governance; and perceptions, beliefs, values and attitudes (Davies et al., 2001).

5. Flesh out the Scenarios – once the quadrants have been defined, the driving forces are revisited and become characters in the stories/scenarios. The idea is to use the two defining forces of each quadrant to frame discussions about what the world might look like and the impact that this world would have on the organisation or entity under discussion, as is shown in Figure 3 over the page. The result is a series of 4 possible future scenarios that assist the organisation to plan for a wide variety of possible future outcomes, facilitating a more thorough planning process.

Scenarios are powerful planning tools precisely because the future is unpredictable. Unlike traditional forecasting or modelling techniques, scenarios present alternative images instead of extrapolating current trends from the present. Scenarios also embrace qualitative perspectives and the potential for sharp discontinuities that quantitative models tend to exclude. Consequently, creating scenarios requires decision makers to question their broadest assumptions about the way the world works so they can foresee decisions that might be missed or denied.

2.9 Interactive Planning

Interactive Planning (Ackoff, 1979) is a way to develop a clear understanding of what must be done to move an organisation forward from its current state, the *Mess*, to its ideal state, the *Design*. It is an interactive process that aims to design a desirable organisational future and identify the ways of bringing it about.

Interactive Planning starts with **Mess Formulation**. A *Mess* is a set of interdependent problems. The Mess Formulation requires a focus on the current business situation and analysis of three dimensions of the organisation: the function, structure, and the critical processes of the organisation. Once a clear understanding of these dimensions is reached, the internal and external obstacles that can impact on the organisation's ability to achieve these goals (such as trends, competition, innovation) needs to be considered. Finally, a reference scenario is generated to demonstrate the dire consequences of not taking action. The second step, the **Design Process**, challenges participants to think creatively and out of the box. The goal of the Design phase is to create a new and exciting view of the organisation, unconstrained by the existing picture of what is possible. Through an iterative process the corporate vision, mission, product and market mix, operational processes, and organisational structure are all defined. In the final stages, the Design is checked against the reference scenario to be sure that all issues, roadblocks, and interdependent problems are dissolved or accounted for. Finally, as the planning process moves into **Means Planning**, a set of strategic initiatives and operational tactics are developed to achieve the exciting new view of the organisation.

2.10 Robustness Analysis

Robustness Analysis (RA) provides an approach to the structuring of problem situations in which uncertainty is high, and where decisions can or must be staged sequentially. The specific focus of RA is on how the distinction between decisions and plans can be exploited to maintain flexibility under uncertainty (Rosenhead, 1980). RA does this by identifying early decisions which allow a range of options and therefore add a degree flexibility to the decision-making process. RA is an iterative process where analysts and participants assess the compatibility of:

- alternative initial commitments (current and committed states of the system that together specify the impending system) with
- possible future configurations of the system being planned for; and the performance of each configuration in a feasible future environment.

The result is a list of possible decisions rated in terms of their robustness against a variety of projected futures.

2.11 Meta- and Hypergames

Metagame analysis is an interactive method of analysing cooperation and conflict among multiple actors (Howard, 1993). Analysts elicit from actors various decision options which are then used to construct possible future scenarios. Threats and promises are then used to explore both the researcher's and actor's abilities to stabilise the outcome at a more preferred scenario to determine the most credible scenarios. Hypergame analysis is another interactive approach which focuses on complex problems in conflict situations that are under the partial control of multiple actors (Bennett & Cropper, 1986). Hypergaming explores the pattern and nature of interactions between the actors and the effects of the differences in perception between the actors regarding their preferences between different outcomes and actions. Having established these preferences they can be mapped and analysed to determine what the best courses of action would be to take in conflict situations.

2.12 Repertory Grid Technique

The Repertory Grid Technique (RGT) is based on the theory of personal constructs (Kelly, 1955). The theory posits that individuals interpret the world in terms of their own personal set of constructs, where constructs are bipolar abstractions that a given individual uses to distinguish between similar and different elements in the world (elements are the objects of an individual's thinking to which they relate their concepts or values). The extent to which two individuals share a similar set of constructs indicates the extent to which they experience and understand the world in similar ways. The RGT is a method for exploring an individual's personal construct system and its organisation in order to understand the world of meaning in which that individual lives. It enables a researcher to unpack the system of constructs a given individual uses to make sense of some particular event, context, or set of objects in the

world. RGT consists of two main phases: a knowledge elicitation phase and a rating grid phase.

1. Knowledge Elicitation Phase – in this phase the elements related to the subject being studied are listed. Through interviewing, a range of qualities (or constructs) used to describe the elements is elicited and recorded in a matrix. The emergent construct is recorded as the emergent pole or pole 1, and its opposing construct is recorded as the contrast pole, pole 2 (see Figure 4 below).

Emergent Pole	ELEMENTS						Contrast Pole
	Mr X	Ms Y	Mrs Z	Mr A	Mr N	Ms V	
Spontaneous	1	5	1	4	2	3	Scripted
Noisy	5	2	1	3	1	2	Quiet
Intimidating	3	1	1	2	1	1	Approachable

Figure 4: Example Repertory Grid

2. Rating Grid Phase – the constructs are then rated over a range of elements on a 1-5 scale, where a '1' rating is assigned to the emergent pole, a '5' rating to the contrast pole and a '3' being applied to those elements that are characterised by neither pole. A grid of comparisons is then produced that includes scored ratings for each element against each construct (see Figure 4).

Data generated using the RGT can be analysed in several different ways. The most common methods used include factor analysis, principal component analysis, multidimensional scaling (each extract factors in slightly different ways) and cluster analysis (which produces clusters or groups that indicates common attributes). Analyses can be greatly enhanced with the aid of computer software packages and web applications designed specifically for the RGT. Fundamentally, the RGT is simply a way of structuring a conversation to elicit views, information and attitudes on a particular issue.

2.13 Delphi Methods

The Delphi Method, originally designed for predicting future events by the RAND Corporation in the 1950s, is the use of surveys and controlled opinion feedback to collect information; the use of anonymity on the part of the participants; and the use of voting to reduce the need for long discussions and direct debates. The method generally includes 3-5 rounds of intensive questionnaires interspersed with feedback sessions. The aim is simply to generate a guide to consensus in a group (Turoff & Hiltz, 1999). The Delphi Method has been applied successfully, but has also experienced its fair share of criticism. A number of Delphi variants have therefore been developed, responding to both the critiques and the changing needs of analysts (Passig, 1998).

2.13.1 Sequence of Opportunities and Negatives

The Sequence of Opportunities and Negatives (SOON) method was created by Pyke in 1970 (as cited in Passig, 1998), and added to the classical Delphi Method indexes of desirability and feasibility. These indexes were thought to strengthen the success of the results of the classical Delphi Method by identifying and accommodating for the barriers to uptake and reification of outcomes.

2.13.2 Policy Delphi

In contrast to the traditional Delphi Method, the Policy Delphi (PD) does not aim to obtain a consensus among participants. The PD enhances the opportunity for all participants to share their views on the issue at hand thereby generating a myriad of opposing views and potential solutions (Turoff, 1975). This method serves to avoid the bottlenecking problem of the classical Delphi Method by providing a more thorough examination of divergent, rather than consensual, issues.

2.13.3 Decision Delphi

The Decision Delphi (DD) capitalises on the PD design by only involving actual decision makers in the Delphi process (Ranch, 1979). In addition, DD employs quasi-anonymity, where the participants know one another, but their responses are kept anonymous. This is thought to provide a challenge and incentive for participants to actively participate in the process.

2.13.4 On-site Conferencing and Researching

The On-site Conferencing and Researching (OSCAR) conference is run much like the classical Delphi Method - rounds of information gathering and feedback while maintaining participant anonymity (Harkins & Kurth-Schai, 1983). It is a technology of time and event and can be assembled in many ways to achieve alternate understandings of reality.

2.13.5 Qualitative Controlled Feedback

Qualitative Controlled Feedback (QCF), like PD, does not aim to obtain consensus among participants and, unlike PD and the other Delphi methods, obtains qualitative feedback from participants (Press, 1978). As opposed to quantitative feedback, group response means and standard deviations, qualitative feedback allows the researchers to elicit insights, perspectives and nuances not provided by quantitative feedback.

2.13.6 Ethnographic Delphi Futures

Ethnographic Delphi Futures Research (EDFR) combines the classical Delphi Method with the Ethnographic Futures Research of Textor (see Textor, 1979). The result is the assurance that participants will all be intensely involved in generating issues for group

discussion such that the scope and focus of issues under discussion cannot be significantly narrowed or influenced by the researcher (Poolpatarachewin, 1980).

2.13.7 Imen Delphi

Finally, the Imen Delphi (ID) combines the strengths, and seeks to overcome the weaknesses, of most of the Delphi Methods described. ID is, however, based predominantly on the classical Delphi Method and OSCAR, and seeks to promote self-awareness and elicit participants' views about their future through an iterative process of questionnaires and interactive feedback (Passig, 1998).

2.14 Political Economic Sociocultural and Technological, and Strengths Weaknesses Opportunities and Threats Analyses

Political, Economic, Sociocultural, Technological (PEST) or Sociocultural, Technological, Economic, Political (STEP) analysis seeks to identify and assess the external drivers of change that will have an influence on the entity under study, usually an organisation of some description. Each PEST aspect is considered along with any threats and/or opportunities.

The questions asked in PEST analysis include:

What are the relevant Social and cultural factors?

What sort of Technological advances will impact the way we live and work?

What Economic trends could these changes create?

How will Politics respond?

The analysis examines the impact of each of these factors (and their interplay with each other) on the organisation. Participants think of inter-relationships between factors, connecting them up to identify the areas that could have the greatest potential impact, representing the future opportunities and threats. The final stage in a PEST analysis is to use these results and prepare contingency plans to prepare for any threats identified. Factors that lead to opportunities can also be included in planning (Bartol & Martin, 1991). However, research suggests that before PEST results can be used effectively, an understanding of the organisation's own capabilities should be developed. This comes from a Strengths Weaknesses Opportunities and Threats (SWOT) analysis.

When dealing with complex situations in a limited amount of time, trying to address all the issues involved does not often pay off. Rather, strategic planners limit their efforts to those issues that have the most impact on the situation. SWOT analysis provides a framework for identifying these critical issues. First, the focus is on the concerned entity: usually an organisation. Then, analyses are limited to the significant strengths, weaknesses, opportunities, and threats that characterise the situation.

Strengths are *positive* aspects *internal* to the entity.

Weaknesses are *negative* aspects *internal* to the entity.

Opportunities are *positive* aspects *external* to the entity.
 Threats are *negative* aspects *external* to the entity.

The purpose of SWOT analysis is to isolate key issues and to facilitate a strategic approach. A SWOT analysis looks at future possibilities for the organisation through a systematic approach of introspection into both positive and negative concerns. It is a relatively simple way of communicating ideas, policies, and concerns to others. SWOTs can be performed by the individual facilitator or in groups. Group techniques are particularly effective in providing structure, objectivity, clarity and focus to discussions about strategy which might otherwise tend to wander, or else be strongly influenced by politics and personalities. Probably the strongest message from a SWOT analysis is that, whatever course of action is decided, decision-making should contain each of the following elements: building on strengths, minimising weaknesses, seizing opportunities, and counteracting threats (Bartol & Martin, 1991).

2.15 Multimethodology

The practice of combining several methods together within a study is known as multimethodology (Munro & Mingers, 2002). Multimethodology in practice can include the combination of complete methodologies; the combination of methodologies with minor adaptations; or the combination of techniques from different methodologies. The methods to be used in a particular study are affected by the nature of the problem, the context, and the skills and knowledge of the operations researcher. Indeed quite often the design of a study will evolve during the project, leaving the door open for the addition of other methodologies or techniques as required. Researchers such as Munro & Mingers (2002) and Abdel-Malek et al. (1999), have reported that combinations of soft OR methodologies have commonly been used in OR studies for a more robust outcome, with more acceptable results. SSM is the single most predominant methodology to be used as part of a multimethodological study. A number of exploratory techniques including SWOT/PEST, Strategic Choice, Influence Diagrams, Interactive Planning, or Cognitive Mapping can be used to augment SSM. And VSM can be used with SSM to develop richer conceptual models. Other popular combinations include Scenario Planning, Delphi, Strategic Choice and/or Cognitive Mapping for future-related studies.

3. Soft Operations Research in the Defence setting

"In a changing world, the Department of Defense has to cope with increased uncertainty about requirements, rapid changes in technology, changes in organizational structures, and a widening spectrum of missions and operations" (Levis & Wagenhals, 2000, p. 225). It is surprising then that soft OR has been scantily applied in the Defence setting in recent years as the methods described in the previous section clearly have a lot to offer in addressing some of these issues. Following is an overview

of how the selected soft OR methods have been applied in the Defence setting to date in the published literature.

3.1 A Literature Review

A recent meta analysis of futures studies (reported by Davies et al., 2001), found that the great majority of studies used the **Scenario Planning** method including those undertaken by the Defence Evaluation and Research Agency (DERA), the Ministry of Defence (MOD) in the United Kingdom, the Central Intelligence Agency (CIA), and the United States Air Force (USAF), while other studies employed the **Delphi Method**. Some studies then applied **Robustness Analysis** to determine the robustness of existing plans to the range of future scenarios (Davies et al., 2001). The **Scenario Planning** method is also being used here in Australia in a number of Defence groups, such as the Strategy Group on their Asia Pacific 2020 project. Several soft OR studies have also been conducted by the Permanent Joint Headquarters (PJHQ) in the United Kingdom (responsible for management of peacekeeping operations). The studies, described by Holt (1999a), used **Decision Trees** and **Influence Diagrams** to evaluate the number of battalions that might be required for use in Bosnia after the reduction of the North Atlantic Treaty Organisation (NATO) forces in 1998; the **Strategic Choice Approach** to determine a strategy for managing the evacuation of civilians from a country undergoing civil disorder; and concluded with **Metagaming** for conflict evaluation. **Hypergames** have been used to analyse the Falklands conflict as well as the invasion of the Suez Canal (Hipel et al., 1988). **Cognitive Mapping** has been used in the United States to understand and model information dominance in battle management (Perusich & McNeese, 1998); to determine whether the United States should build and deploy a midphase National Missile Defense System within the next 5 years (Horn, 2001); to develop a model of the Royal Navy Anti-Warfare Officers team in the United Kingdom (Holt, 1988); and to characterise Information Operation capabilities in the Canadian military (Garigue, 1998). Both **PEST** and **SWOT** analyses were used by the National Support staff to identify preliminary strategies aimed at ameliorating the vulnerabilities of Australia's critical national infrastructure in the Defence context (PreDICT study, 1998). Researchers at the Los Alamos National Laboratory in the United States used **SWOT** analyses in the initial phases of their Military Space Initiative research (Weber, 2001). The Canadian Defence Force used both **SWOT** analyses and **Strategic Options Development and Analysis (SODA)** to develop their *Defence Strategy 2020* paper (Canadian Defence Force, 1999). SODA was also used by the Swedish National Defence Research Establishment to aid in the analysis and design of a new command and control system (Agrell & Holmberg, 1998). The same team then used **Robustness Analysis** to structure the traps and options of adaptive courses of action. The **Delphi Method** has been used by the United States Army to identify the behaviours and competencies required for leaders and officers to achieve successful careers in the 21st Century (Mangelsdorff et al., 1996). A study conducted by the Centre for Defence Analysis (Sea/Air) in the United Kingdom, investigated the coordination of battlefield digitisation using **Checkland's Soft Systems Methodology (SSM)** to elicit the inputs to, and outputs from, the

coordination process (Holt, 1999b). SSM has also been used here in Australia to analyse the Royal Australian Air Force logistics system (Smith & Watson, 1986); by Sparks (1997) to analyse the acquisition and management of logistics in the Australian Defence Force (ADF); and for the development of military information operations capability in the ADF (Staker, 1999). Yates & Burke (2001) used ideas from **Total Systems Intervention (TSI)** to build a framework to improve evaluations of military organisations. The Swedish National Defence Research Establishment also adapted ideas from TSI for their command and control system research project (Agrell & Holmberg, 1998). Finally, the **Viable Systems Model** was used by Granata et al. (1994) to re-engineer the National Aeronautics and Space Administration's (NASA) Mission Operations and Data Systems Directorate in the United States.

3.2 Accounting for the lack of Soft Operations Research studies in the Defence setting

The lack of soft OR studies within the Defence setting is perhaps not surprising as the choice of methods to use in any particular OR study is as much a product of the knowledge, experience and skills of the researcher as it is about the nature of the problem itself. With the majority of researchers in the Defence setting originating from the hard schools of thinking (such as mathematics, computer science and engineering), it is only natural that they would prefer to apply corresponding methods (Mingers, 2001). There has been considerable resistance, therefore, to use soft OR in the Defence setting, usually coming from these traditional or hard operations researchers (Holt, 1999b). Interestingly this is contrary to the experience of other sectors (such as transportation, health and development) who have embraced the use of soft OR (Rosenhead, 1992). Indeed some feel that the Defence setting is the only place that hard and soft OR truly remain separate entities (Hough, as cited in Holt & Pickburn, 2001).

Doubts over the value of soft OR in the Defence setting concern the correctness or validity of the methods as well as their applicability to the problems with which they are faced. Such doubts include questions about repeatability and robustness; inclusion of perceptions and other subjectivities that are ill-founded; and questions about the expertise of soft operations researchers (Holt & Pickburn, 2001). The general argument has been that hard OR is founded on years of research success stories, whereas soft OR has failed to prove itself. This hard versus soft debate, however, is counterproductive. Soft OR would never purport to replace hard OR, nor should it. The philosophies and theories underlying both hard and soft OR are vastly different and the methods are rarely applicable to the same types or parts of problems (see Figure 5 over the page).

It is encouraging, however, that one of the key conclusions reached in a recent workshop held jointly by the Defence Research Group of the UK Operational Research Society and DERA (Holt & Pickburn, 2001) was "that, with the currently changing political and military environment, there is a need for OA [operations analysis] to support military activity that is servicing political objectives; increased capability to

perform strategic analysis; high levels of decision-making being supported by OA than is currently the case; and the capability to address:

- Short timescale problems with wide stakeholder communities
- Low probability, high impact situations
- Non-warfighting military operations
- Prototype/quick look analysis"

Clearly soft OR has much to offer in these areas and with this in mind the workshop further concluded that hard and soft OR methods "should be viewed as equally useful in the analyst's toolkit" and that a "framework for incorporating soft OA into current analysis is required" (Holt & Pickburn, 2001, p. iii, p. 19). It is only with this kind of support that soft OR may one day become a key force in military operations research.

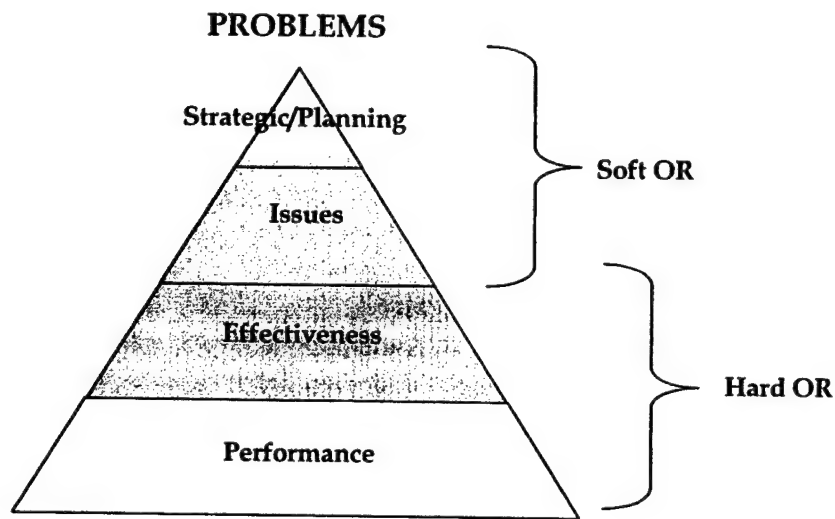


Figure 5: Types of Problems and Corresponding School of OR (Clutterbuck, 2001)

4. Future Directions for Soft Operations Research in Defence

So where to for soft OR in military operations research? There seems to be two obvious paths that soft OR can take at present. One is to complement the many hard OR studies currently undertaken and the second, requiring considerable support however, is to address the many complex problems Defence faces today, particularly the social, political or cultural dimensions of those problems.

4.1 Multimethods and Multiparadigms - Introducing Composite Operations Research

As can be gleaned from the discussion thus far, OR provides the researcher with a plethora of methods and this has opened up the possibility of linking or combining methods in a particular study. In addition, a particularly pervasive problem with traditional OR has been its inability to accurately represent human factors. This is where the use of multiple methods, crossing multiple paradigms, can add value to any OR project. Indeed one of the key conclusions reached in a recent workshop held jointly by the Defence Research Group of the UK Operational Research Society and DERA was that there "should be an increased emphasis on multi-methodology approaches" (Holt & Pickburn, 2001, p. iii). Research has found that operations researchers have combined multiple hard methods; multiple soft methods; and, although less frequently, hard and soft methods. On average 2-3 methodologies are used together (Munro & Mingers, 2002). The table below presents an overview of the top 5 most used combinations of the various groupings of methodologies.

*Table 4: The Top Combinations of OR Methodologies
(Munro & Mingers, 2002; Abdel-Malek et al., 1999)*

Hard and Hard	Soft and Soft	Soft and Hard
1. Simulation and Statistics 2. Forecasting and Statistics 3. Mathematical Modelling and Statistics 4. Mathematical Modelling and Simulation 5. Mathematical Modelling and Heuristics	1. SWOT/PEST and SSM 2. Influence Diagrams and SSM 3. Strategic Choice and SSM 4. Interactive Planning and SSM 5. Cognitive Mapping and SSM	1. Simulation and SSM 2. Statistics and SSM 3. Structured Analysis and Design and SSM 4. Statistics and Cognitive Mapping 5. Statistics and Influence Diagrams

Although there are relatively few combinations of hard and soft OR methodologies being used today, combining methods has been judged to be very successful according to operations researchers (Munro & Mingers, 2002). In the Defence setting, "successful complementary use of hard and soft methods can have a number of significant advantages including minimising judgement, promoting awareness and improving buy-in for studies" (Clutterbuck, 2001). In addition, the combination of any OR methods, be they hard or soft, with the social sciences, be it psychology, sociology or anthropology, is another way to ensure that human factors are accurately represented (Holt, 2000). Clearly there is a role for soft OR to play in complementing hard OR methods and the social sciences in the future. Indeed the Swedish National Defence Research Establishment recently called such a combination of methods 'composite OR' (Agrell & Holmberg, 1998). Composite OR has arisen in response to lessons learned; changing methods; and increasingly complex problems. As the researchers say "it will be a new kind of science, not just general interdisciplinary but a rich composite of engineering, arts and humanities based both on theory and on experience" (Agrell &

Holmberg, 1998, p. 65). The case of asymmetric conflict, to follow, is but one issue that this composite OR could be applied to.

4.2 The Contributions of Soft Operations Research - the Case of Asymmetric Conflict

In a recent survey of OR professionals "the interviewees could not say enough about the need to address the socio-political side of the problem...The survey revealed the importance of non-quantitative OR methods in practice" (Abdel-Malek et al., 1999, p. 1001). The terrorist attacks on both New York City and Washington DC on September 11, 2001 (9/11) have brought about a plethora of research interest in asymmetric conflict. For researchers involved in terrorism-related research one thing seems clear: "soft facts are the rule; hard data is seldom available" (Liebel, 2002, p.174). What has become apparent since 9/11 is that there needs to be a better understanding of these soft facts (Eash, 2002). Indeed "military analysis must take more account of political, economic and other factors" (Holt & Pickburn, 2001, p. 13). To revisit the critiques of Ackoff (1979) and Checkland (1983), and with the events of 9/11 in mind, OR practice must now be considerably more diverse than striving for optimisation through mathematical modelling alone. Problems have become increasingly complex and the standard formulations of OR methodology are limited in their application to these less well-behaved situations, particularly the human aspects. There is now a renewed focus on understanding who the faces behind the threats are; to establish a profile of their physical, cultural, psychological and social characteristics; and ultimately be able to model (and predict) their behaviour (Hudlicka & Zacharias, 2001). A common concern among model developers, however, is to increase their realism in a variety of cultural, political, psychological, and social states (Silverman et al., 2002). We now also need the ability to assess 2nd order and beyond effects. For instance, the current tools in use (the hard tools) are not able to effectively examine how the use of military force will influence the will of an adversary, nor are they able to assess whether outcomes can be achieved by capabilities other than military force (Saunders-Newton, 2002). Hard OR methods simply do not allow for the examination of the highly complex structure and interaction of socio-cultural systems, and are often riddled with complexities. Indeed this has been a common criticism of OR practice. In the past "OR practitioners have been hung up on complexity when decision makers need something simple and immediate" (Holt & Pickburn, 2001, p. 13). For decision makers involved in the analysis of asymmetric threats, for instance, "two key questions need to be addressed - *what new crisis may erupt?* and *what are the triggers and cliff edges?*" (Holt & Pickburn, 2001, p. 13). Only then can policies and plans be developed, modelled and evaluated.

It seems clear then that there is an important role for soft OR to play in understanding and analysing problems of this social and political complexity. Some methodological suggestions for the structuring, and analysis of asymmetric conflict-related problems include:

- Using a SWOT analysis as a preliminary exercise to identify what effects the asymmetric threat may have on the entity under discussion, be that the military

apparatus or other key players. Decision-making and planning should then seek to build on the identified strengths, minimise the weaknesses, seize the opportunities and counteract the threats.

- Using a **PEST** analysis to flesh out the external drivers of change (political, economic, sociocultural and technical) that could impact on the future, particularly with regards to asymmetric conflict (both the military and individual asymmetric threats/groups); to identify future opportunities, threats and their triggers; to develop preliminary strategies; and to inform futures analysts.
- Using **Cognitive Mapping** to identify and link key players pictorially in the asymmetric arena, in order to gain a better understanding of the problem/s to be addressed and their interrelatedness.
- Using Checkland's **Soft Systems Methodology** to understand the socio-cultural aspects of the problems associated with asymmetric conflict; to identify the ideal situations and compare these to the current situation or real world; to identify the changes required to the current situation to bring it in line with the ideal; and to develop action plans to effect the changes deemed worthy of effort.
- Using the **Strategic Choice Approach** to encourage collaboration between key players from a variety of backgrounds; for managing the high level of uncertainty surrounding asymmetric conflict; to stimulate the development of plans and strategies; and to prioritise those decisions and plans to be made now and in the future.
- Using **Delphi** to envision the future of asymmetric conflict; to generate a guide to consensus as to a way, or ways, forward; and to develop policies and plans.
- Using **Scenario Planning** to define and understand the impact of external driving forces and triggers that may affect the future with regards to asymmetric conflict; to envision what new crises may erupt; and to evaluate and refine policies and plans developed using other methods.
- Using **Robustness Analysis** to identify those policies or plans that are highly robust with regards to the range of projected future scenarios developed via Delphi and/or Scenario Planning.
- Combining the above with a wide variety of **hard OR** methods such as:
 - **Wargaming and Simulation** – to perceive and analyse interactions and further evaluate the policies and plans.
 - **Bayesian Belief Networks** – to measure the effects of certain events on each other.
 - **Rule or Cased Based Reasoning** – to validate the correctness of models and verify if the models work as intended.

It is relevant to add here that the addition of selected social science methods and theories, with a particular focus on human behaviour, would serve to strengthen the analysis of asymmetric threats, indeed most Defence-related issues. It is with this in mind that some researchers have recently begun calling for greater collaboration between operations researchers and social scientists, particularly psychologists (Holt,

2000; von Baeyer, 2002). This is a topic that has been explored further in a subsequent paper (Heyer, 2004).

4.3 The Future of Soft OR in the Defence Setting

It should be stressed that more work needs to be done to inform military operations researchers on the application of soft OR methodologies in the Defence setting to Defence-specific problems. What seems clear is that in order for soft OR to be widely accepted and applied in Defence research it needs a champion. The newly formed OR Hub of the Defence Science and Technology Organisation could provide a fora for discussions about methodologies and models, promote skills development and even encourage the formation of a community of practice in soft OR. A clear recommendation following from this is that the Hub include in its terms of reference a commitment to furthering soft OR in Defence research, where appropriate.

4.4 A Preliminary Framework to Guide the Application of Soft Operations Research Methodologies

It is useful at this point to summarise the discussion of the methodologies presented in this paper by providing a preliminary framework to guide their application. The following table (see Table 5 overleaf) broadly defines the type of problem and the methodology/ies suggested for addressing it. The outcomes of the applications are also described, to further aid decision-making regarding the relevant method to adopt.

Table 5: A preliminary framework to guide the application of Soft Operations Research methodologies

Type of Problem	Methodology	Outcome
<i>Need to better understand the client's perception of the problem</i>	a. Soft Systems Methodology b. Influence Diagram c. Cognitive Mapping d. Repertory Grid Technique e. Total Systems Intervention	a. Rich pictures to understand the people, culture and politics surrounding the problem, root definition, conceptual models to understand linkages b. A simple visual representation of the problem c. A map of the client's subjective perception of the problem d. An understanding of the client's world of meaning and perception e. A wide range of stakeholder understandings of the problem and problem classification to inform methodology choice
<i>Several courses of action possible, can't make up mind</i>	a. Decision Tree b. Journey Making	a. A visual representation of the problem and the possible options enabling the decision maker to investigate the outcomes of choosing particular options b. Identification of the set of options most likely to be successfully implemented
<i>Problems with a high level of uncertainty:</i> i). general problems ii). strategic-level problems	ia. Robustness Analysis iia. Strategic Choice Approach iib. Scenario Planning	ia. A list of possible decisions rated in terms of their robustness against a variety of projected future situations iia. The 'commitment package' - an agreement between decisions to be made now and in the future iib. Scenario Planning matrix, detailing critical uncertainties, with which to evaluate policies and plans
<i>Strategic/Futures Issues:</i> i). general ii). organisational iii). where differences of opinion are preventing a group's ability to tackle ill-structured problems	ia. SODA ib. Scenario Planning ic. PEST/STEP SWOT iia. Interactive Planning iib. Viable Systems Model iiia. Journey Making iiib. SAST iiic. Delphi Methods	ia. Cognitive maps, detailing emergent themes and concepts, guiding subsequent discussions ib. Scenario Planning matrix with which to evaluate policies and plans ic. Identification of positive and negative concerns Contingency plans for dealing with future threats iia. A clear understanding of how to progress the organisation from the current to desired state iib. Identification of goals, signals and their associated gaps, strategies offered to close gaps to achieve organisational viability iiia. Identification of the set of options most likely to be successfully implemented iiib. The group's preferred strategy is identified iiic. Group consensus on strategic issues is achieved
<i>Analysis of interactions, cooperation and conflict among multiple actors</i>	a. Metagames b. Hypergames	a. Identification of decision options and construction of possible future scenarios b. Understanding of differences in perception between actors, maps to determine best course of action in future conflict
<i>Need to identify areas for change</i>	Soft Systems Methodology	Identification of changes to be made and development of action plans to effect change

5. Conclusion

Over the years problems in human-machine systems have become increasingly complex and unpredictable. This has perhaps been most evident in the Defence setting where there has been an increase in uncertainty about requirements; wider stakeholder communities; changes in organisational structures; a wider spectrum of military and non-warfighting operations and missions; and an increase in terrorism. Standard formulations of OR methodology, particularly those that are, in Checkland's words, "wedded to logic", have not coped well with these less well-behaved situations. OR has, more recently, required methods that enable decision makers to accommodate multiple perspectives; facilitate negotiating joint agendas; function through interaction and iteration; and generate ownership of problem formulation. This is where soft OR, including methods such as Checkland's Soft Systems Methodology, Cognitive Mapping and Scenario Planning, makes a contribution. It is surprising, therefore, to report that soft OR has not been applied often in the Defence setting in recent years. Soft OR clearly has a lot to offer in addressing some of the increasingly complex issues facing the Department of Defence today, particularly the socio-cultural aspects. Although surprising, the lack of soft OR studies within the Defence setting is perhaps not unexpected as the choice of methods to use in any particular OR study is as much a product of the knowledge, experience and skills of the researcher as it is about the nature of the problem itself. For this reason, the future for soft OR in the Defence setting, in the short term at least, seems to be in its ability to complement hard methods. Although there are relatively few combinations of hard and soft OR methodologies being used today, combining methods has been judged to be very successful. However, in order for soft OR to gain credence in military operations research, and perhaps stand on its own two feet, it first needs to be recognised as equally useful in the operations researcher's toolkit. Secondly, a framework for incorporating soft OR into current military operations research needs to be developed and promulgated. Lastly, there needs to be a commitment to skill development for operations researchers in the use of soft OR methods. The newly formed OR Hub in the Defence Science and Technology Organisation could contribute to the development of this recognition, framework and skills in soft OR.

To ignore the key role that soft OR has to play in addressing particularly complex and unpredictable problems; to treat it as secondary to hard OR; to fail to incorporate it into military operations research; and to fail to develop skills in the area may be to the detriment of OR itself. As Rosenhead warns: "operations research should pay attention to developments and changes, actual or projected, in the material base of its potential users...such developments and changes have eroded OR's traditional base, and are likely to continue to do so" (Rosenhead, 1998, p. 408).

6. References

- Abdel-Malek, L., Wolf, C., Johnson, F. & Spencer III, T. (1999). OR Practice: survey results and reflections of practicing INFORMS members. *Journal of the Operational Research Society* 50: 994-1003.
- Achterbergh, J. & Vriens, D. (2002). Managing Viable Knowledge. *Systems Research and Behavioral Science* 19: 223-241.
- Ackoff, R.L. (1979). Resurrecting the future of operational research. *Journal of the Operational Research Society* 30(3): 189-199.
- Ackoff, R.L., Gupta, S.K. & Minas, J.S. (1962). *Scientific Method - Optimizing Applied Research Decisions* Wiley: New York, as cited in Liebl, F. (2002). The anatomy of complex societal problems and its implications for OR. *Journal of the Operational Research Society* 53: 161-184.
- Agrell, P.S. & Holmberg, S. (1998). Operational Research in Swedish Military Long-term and Complex Development Projects. *Systems Research and Behavioral Science* 15: 61-65.
- Bartol, K. M., & Martin, D. C. (1991). *Management*. New York: McGraw Hill, Inc.
- Beasley, J.E. (2002). OR-Notes available at:
<http://mscmga.ms.ic.ac.uk/jeb/or/softor.html>
- Beer, S. (1985). *Diagnosing the System*. Wiley, Chichester.
- Bennett, P.G. & Cropper, S.A. (1986). Helping people choose: Conflict and other perspectives in Belton, V. & O'Keefe, R. (eds.) *Recent Developments in OR*. Pergamon Press, UK pp 13-25.
- Canadian Defence Force (1999). *Shaping the Future of Canadian Defence: A Strategy for 2020: Formulation of the Statement of Strategy* available at:
<http://www.vcds.forces.gc.ca/dgsp/cosstrat/2020/dwnld/Defence%20Strategy%202020%20Ver4.doc>
- Carter, M.W. & Price, C.C. (2001). *Operations research: a practical introduction*. CRC, Boca Raton, USA.
- Checkland, P. (1999). Soft Systems Methodology: A Thirty-Year Retrospective. *Systems Research and Behavioral Science* 17: S11-S58.

- Checkland, P. (1983). O.R. and the Systems Movement: Mappings and Conflicts. *Journal of the Operational Research Society* 34(8): 661-675.
- Clutterbuck, J. (2001). *Is Complementary Strategy the Way Forward?* Key Note Address at the OA Techniques for the Future Workshop 31 January 2001 (DERA and UK Operational Research Society).
- Daellenbach, H.G. (2002). *Hard OR, Soft OR, Problem Structuring Methods, Critical Systems Thinking: A Primer*. Unpublished Paper, University of Canterbury, NZ.
- Davies, S., Bollard, B, Fisk, K. & Purvis, M. (2001). *Strategic Futures Thinking: meta analysis of published material on Drives and Trends*. DERA Report: DERA/DSTL/CR00979/2.0
- Eash, J. (2002). *Soft Science, Hard Problems: The Future Role of the Social Sciences and Agent-Based Modeling in DOD*. Presentation to the 1st Lake Arrowhead Conference on Agent-Based Models, May 11, 2002.
- Eden, C. (1992). On the nature of cognitive maps. *Journal of Management Studies* 29(3): 261-265.
- Eden, C. & Ackermann, F. (1998). *Making Strategy: The Journey of Strategic Management*. Sage Publications, UK.
- Eden, C. , Jones, S. & Sims, D. (1983). *Messing About in Problems*. Pergamon Press, UK.
- Flood, R.L. & Jackson, M.C. (1991). *Creative Problem Solving: Total Systems Intervention*. Wiley, Chichester.
- Friend, J.K. & Hickling, A. (1987). *Planning Under Pressure*. John Wiley & Sons, UK.
- Garigue, R. (1998). *The Application of Cognitive Mapping to Characterize Information Operation Capabilities*. National Defense HQ, Department of National Defense, Canada.
- Granata, R.L., Oran, W.A., Beyer, D. S., Mayer, D.S., Mackey, W.F., Yost, R.F., Van Nostrand, G.C., Karlin, J.J. & Bagg III, T.C. (1994). *A Systems Engineering Analysis for Re-engineering an Organization*. Paper presented to the INCOSE International Symposium, 1994.
- Harkins, A. & Kurth-Schai, R. (1983). OSCAR: an applied social technology variant of the Delphi method *Futurics* 7(3): 1-7.
- Heyer, R.L. (2004). *Operations Research and the Social Sciences: what are the distinctions and how can they be used in the Defence environment?* Unpublished Paper, DSTO Information Sciences Laboratory.

Hipel, K.W., Wang, M. & Fraser, N.M. (1988). Hypergame analysis of the Falkland/Malvinas Conflict. *International Studies Quarterly* 32: 335-358.

Holt, J. (2000). OR on the Psychologist's Couch – how OR and psychology could work together *OR Insight* 13: 21-32.

Holt, J. (1999a). *Two Faces of Soft OR for Military OA*. Presentation to the Defence Study Group of the OR Society, DERA Farnborough.

Holt, J. (1999b). Should Military OR go soft? *UK Operational Research Society Newsletter* October 1999.

Holt, J. (1988). Assessing the need for decision support systems. *European Journal of Operational Research*. 17: 73-82.

Holt, J. & Pickburn, G. (2001). OA Techniques for the Future. DERA/CDA/SEA/AIR/CR000141.

Horn, R.E. (2001). *Knowledge Mapping for Complex Social Messes*. Unpublished Paper, Stanford University. Available at:
<http://www.stanford.edu/~rhorn/images/SpchPackard/spchKnwldgPACKARD.pdf>

Howard, N. (1993). The role of emotions in multi-organisational decision-making. *Journal of the Operational Research Society* 44(6): 613-623.

Howard, R.A. & Matheson, J.E. Eds. (1981). *Readings in the Principles and Applications of Decision Analysis*. Menlo Park, CA: Strategic Decisions Group.

Hudlicka, E. & Zacharias, G. (2001). *Individual Differences and Social Networks: Implications for Modeling Asymmetric Warfare*. Presentation to the 9th Computer Generated Forces Conference in Miami, Florida.

Kelly, G.A. (1955). *The psychology of personal constructs, Vol. 1: A theory of personality*. New York: W. W. Norton and Company.

Levis, A.H. & Wagenhals, L.W. (2000). C4ISR Architectures: 1. Developing a Process for C4ISR Architecture Design. *Systems Engineering* 3(4): 225-247.

Liebl, F. (2002). The anatomy of complex societal problems and its implications for OR. *Journal of the Operational Research Society* 53: 161-184.

Machol, R.E. (1980). Comment on "Publish or perish". *Journal of the Operational Research Society*. 31: 1109-1110.

- Mangelsdorff, D.A., Finstuen, K., & Rogers, J.R. (1996). Forecast for Success - U.S. Army Medical Service Corps Officers available at: <http://www.ijoa.org/imta96/paper06.html>
- Mason, R.O. & Mitroff, I.I. (1981). *Challenging Strategic Planning Assumptions*. John Wiley & Sons, New York.
- Mingers, J. (2001). *Future Directions in Soft OR – Multi-Methodology*. Key Note Address at the OA Techniques for the Future Workshop 31 January 2001 (DERA and UK Operational Research Society).
- Munro, I. & Mingers, J. (2002). The use of multimethodology in practice – results of a survey of practitioners. *Journal of the Operational Research Society* 53: 369-378.
- Omerod, R.J. (2001). Viewpoint. The success and failure of methodologies – a comment on Connell (2001): evaluating soft OR. *Journal of the Operational Research Society* 52: 1176-1179.
- Passig, D. (1998). An Applied Social Systems Procedure for Generating Purposive Sound Futures. *Systems Research and Behavioral Science* 15: 315-325.
- Perusich, K. & McNeese, M.D. (1998). *Understanding and Modelling Information Dominance in Battle Management: Applications of Fuzzy Cognitive Maps*. West Lafayette, Purdue University.
- Pidd, M. (1999). A brief introduction to 'soft' operational research in *Handling Strategic Problems* available at: http://www.orsoc.org.uk/about/teaching/StrategicProblems/m_4.htm
- Poolpatarachewin, C. (1980). Ethnographic Delphi futures research: Thai University pilot project. *Journal of Cultural and Educational Futures* 2(4): 11-19.
- PreDICT (Predict Defence Infrastructure Core Requirements Tool) Study (1998). at: <http://203.6.115.8/predict/>
- Press, S.J. (1978). Qualitative controlled feedback for forming group judgments and making decisions. *Journal of the American Statistical Association* 73(363): 526-535.
- Pyke (1970). *Distribution of Characteristics of the Sulphide Ores of the Timmins Area*. Department of Mines, Toronto. As cited in Passig, D. (1998). An Applied Social Systems Procedure for Generating Purposive Sound Futures. *Systems Research and Behavioral Science* 15: 315-325.
- Ranch, W. (1979). The decision Delphi. *Technological Forecasting and Social Change* 15(3): 159-169.

Rosenhead, J.V. (1998). Success and survival – A comment. *The Journal of the Operational Research Society* 49(4): 408-412.

Rosenhead, J.V. (1996). What's the problem? An introduction to problem structuring methods. *Interfaces* 26(6): 117-131.

Rosenhead, J.V. (1992). Into the Swamp: The Analysis of Social Issues. *The Journal of the Operational Research Society* 43(4): 293-209.

Rosenhead, J.V. (1980). Planning under uncertainty 2: A methodology for robustness analysis. *Journal of the Operational Research Society* 31(4): 331-341.

Saunders-Newton, D. (2002). *Social Science Theory, Operations Research & Computational Models: National Security Studies as a Nexus of Inquiry Approaches, (or...Why Breaking Things Doesn't Always Get You What You Want)*. Presentation to the 1st Lake Arrowhead Conference on Agent-Based Models, May 11, 2002.

Schwartz, P. (1996). *The Art of the Long View: Paths to Strategic Insight for Yourself and Your Company*. Second edition. New York: Doubleday Currency.

Silverman, B.G., Johns, M., O'Brien, K., Weaver, R. & Cornwell, J. (2002). *Constructing Virtual Asymmetric Opponents from Data and Models in the Literature: Case of Crowd Rioting*. Available at: <http://www.seas.upenn.edu/~barryg/Protest.pdf>

Smith, R. & Watson, R.B. (1986). A Macro Analysis of the RAAF Logistics System - A Case Study in the Application of Soft Systems Methodology. *ASOR Bulletin* 6(2): 14-21.

Sparks, J.N. (1997). *Soft operational research techniques for the acquisition and management of logistics*. Canberra: Directorate of Publishing and Visual Communications, Defence Centre-Canberra.

Staker, R.J. (1999). An application of Checkland's Soft Systems Methodology to the development of a military information operations capability for the Australian Defence Force. DSTO-TN-0183.

Textor (1979). The natural partnership between ethnographic futures research and futures education. *Journal of Cultural and Educational Futures*. 1(1): 13-19.

Travis, J. & Venable, J.R. (2002). *An Introduction to Soft Systems Methodology*. Available at: http://cispom.boisestate.edu/cis310emaxson/ssm_intro.htm

Turoff, M. (1975). The Policy Delphi. In *Delphi method – Techniques and Applications*. Linston, H.A. & Turoff, M. (eds.) p. 6-15.

Turoff, M. & Hiltz, S.R. (1999). *Computer Based Delphi Processes*. Available at: <http://eies.njit.edu/~turoff/Papers/delphi3.html>

von Baeyer, A. (2002). *The Relevance of Human Behaviour Representation in Future C2 Systems: Current and Future Research Approaches*. Paper presented at the Analysis of the Military Effectiveness of Future C2 Concepts and Systems Symposium held at the NATO Consultation, Command and Control Agency, The Hague, 23-25, 2002. Available at: <http://www.nc3a.nato.int/symposia/sas039/proceedings/B7.doc>

Warren, L. & Adman, P. (1999). The Use of TSI in Designing a System for a University IS User Support Service. *Systems Research and Behavioral Science* 16: 351-358.

Weber, P. (2001). *Military Space Initiative*, Los Alamos National Laboratory. Available at: <http://www.lanl.gov/orgs/p/pdfs/milspace.pdf>

Yates, A. & Burke, M. (2001). *Improving Evaluations of Military Organisations*. Paper presented at the 6th International Command and Control Research and Technology Symposium, United States Naval Academy (Annapolis, Maryland), June 19-21, 2001.

Appendix A: An Application of Checkland's Soft Systems Methodology

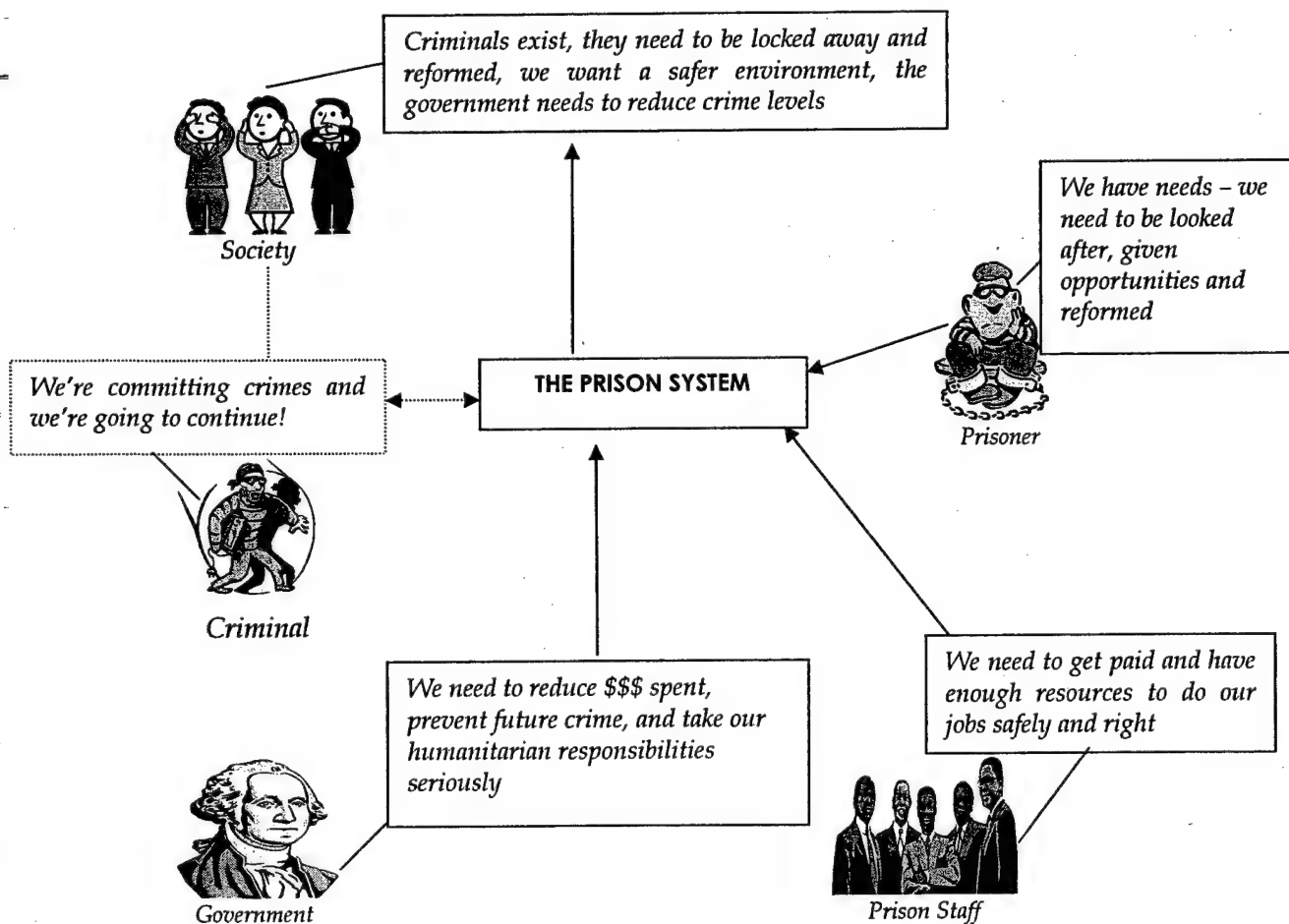
Example adapted from Beasley (2002).

The Problem

Crime is a real problem in this country. We are spending more and more on locking up increasing numbers of people in prisons, yet crime seems to go on rising. Many of those in prison are there for reasons connected with medical problems (e.g. drug addiction, mental illness), yet when they come out these problems are unresolved and so they go straight back to the crime. Perhaps the answer is longer prison sentences.

In Stage 1-2 we enter the problem situation and identify the people, the culture and the politics within it. This is sometimes achieved through the development of a rich picture.

A simple rich picture for the current problem may look like this:



In Stage 3 the root definition is developed using the CATWOE mnemonic:

C: customer is society

A: actors are the prisoners and prison staff

T: transformation process is the need for convicted criminals to be locked away from society to the need being met

W: the worldview is the desire to reform criminals and prevent future crime

O: the owner is the government

E: the environmental constraint is that criminals exist

From this the following root definition can be formed:

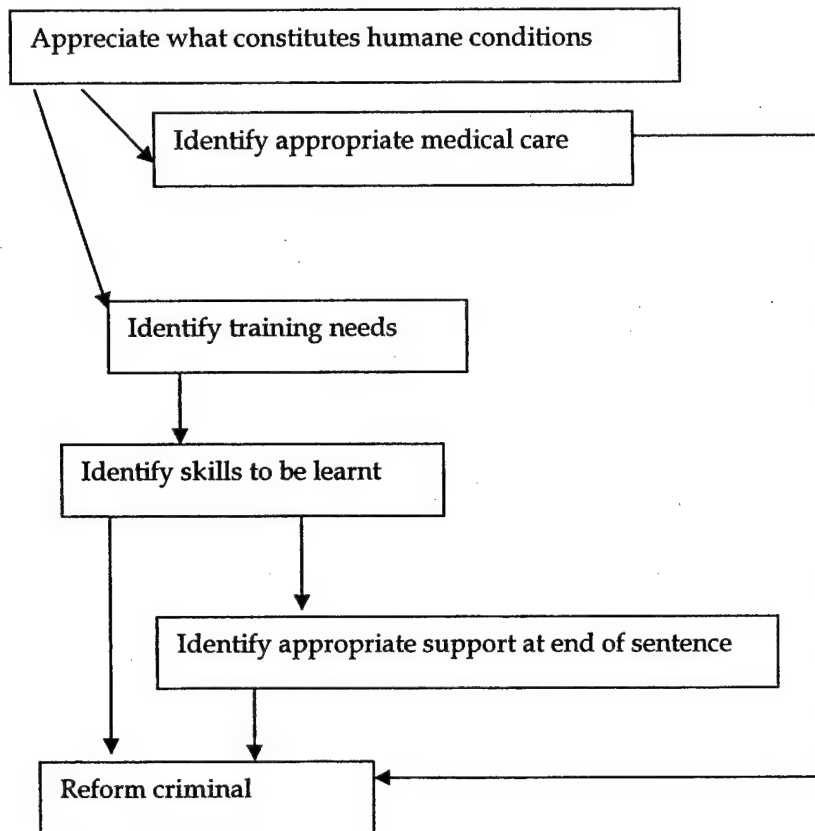
The prison system is a system for ensuring convicted criminals (prisoners) serve their sentences in humane conditions, receive appropriate medical care and are given opportunities for training and to learn new skills, and are released back into society at the end of their sentence with appropriate support so that they reform from their life of crime.

In Stage 4 a conceptual model of the activities needed by the root definition is developed.

With respect to the root definition developed above some of the activities could be:

- Appreciate what constitutes humane conditions
- Identify appropriate medical care
- Identify training needs
- Identify skills to be learnt
- Identify appropriate support at end of sentence
- Reform criminal

These could be linked in a conceptual model as over:



In Stage 5 the models that have been developed, such as that above, are compared with the real world.

For each activity in the conceptual model we ask:

- Does this happen in the real situation? (i.e. is appropriate medical care currently identified?)
- How?
- By what criteria is it judged?
- Is it a subject of concern in the current situation?

We may conclude from this that we are not making sufficient effort to identify appropriate medical care. This leads to the next step.

In Step 6 we identify changes to be made to the real world system.

Using the example, we have concluded in Step 5 that we are not making sufficient effort to identify appropriate medical care. We might, therefore, identify putting more resources into medical assessment/care of prisoners as a change to be made.

In Step 7 we take action to put the proposed changes into practice.

In this example we'd develop action plans for lobbying government, identify available resources, evaluate possible programs to improve current service etc.

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19. ABSTRACT

This paper seeks to understand soft operations research (OR) - the distinctions between it and hard OR, its methods and their application, particularly in the Defence setting. To achieve this a detailed examination of selected soft OR methods is presented, followed by a literature review documenting applications of these methodologies in the Defence setting, and the development of a preliminary framework to guide application of the methods. The paper concludes with an examination of the way forward for soft OR in the Defence setting, recommending support for soft OR's use in future projects, either singularly or in combination with hard OR methods; and the development of a framework for incorporating soft OR into current military operations research.